MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVII. MAY 14, 1897. No. 7

Sir R. S. BALL, M.A., LL.D., F.R.S., President, in the Chair.

Arthur W. Clayden, M.A., F.G.S., St. John's, Polsloe Road, Exeter; and
Herbert Lovis Noel Noel-Cox, 2 Edinburgh Mansions, Victoria Street, S.W.,

were balloted for and duly elected Fellows of the Society.

Seventy-eight presents were announced as having been received since the last meeting, including, amongst others :—

E. S. Holden, Mountain Observatories, presented by the Author; J. A. C. Oudemans, Triangulation von Java, Abtheilung V., presented by the Netherlands Government; J. Milne and W. K. Burton, The Great Earthquake in Japan, presented by Professor Milne; Lick Observatory Atlas of the Moon, plates 2–5, presented by the Observatory; Harvard College Observatory, photographs taken with the Bruce telescope, presented by the Observatory; Photograph of *Jupiter* by Warren De la Rue, presented by Mr. G. F. Pollock; Lantern slides of the Sun-spots of May 1897, presented by Mr. Newbegin.

P P

On the Various Forms of Personal Equation in Meridian Transits of Stars. By Truman Henry Safford.

The first and historically the most important form of personal equation is that discovered by Bessel in the use of the eye and ear method.

In Bessel's Memoir we find the examples of large personal equations which are most frequently quoted; and to illustrate some of the points I will repeat them. Bessel anticipated Argelander $1^{s}\cdot22$ by eye and ear, and also anticipated W. Struve by $0^{s}\cdot8$. This last value held good strictly for the year 1821, and at that time it was indirectly obtained through Walbeck; and a closer agreement of Bessel and Struve, B.-S. $= -0^{s}\cdot044$, is sometimes quoted. It was found in 1814; and the evidence for it is slight, one transit of *α Lyræ* by Struve and one each of *α Andromedæ* and *γ Pegasi* observed by Bessel. It is not unfair to suspect that the apparent change in Struve's personal equation relatively to Bessel from $0^{s}\cdot04$ in 1814 to $0^{s}\cdot8$ in 1821 was due to irregularity of clock rate on 1814 October 21, more than to a change in the personal equation of either astronomer.[1] *Fomalhaut*, observed by Bessel and Struve 1820 November 13, gave Bessel-Struve $= -0^{s}\cdot68$, but the observation was passed over as too near the horizon of Konigsberg, where the star's altitude was $4^{\circ}1\text{-}2$; yet it agrees well enough with later determinations of Bessel and Struve's personal equation.

Bessel and Argelander inferred from their unprecedented difference of $1^{s}\cdot22$ that Bessel anticipated the true time of transits, while Argelander fell behind it. Bessel, when he used a half-seconds timepiece, observed $0^{s}\cdot5$ later than with the sidereal clock; hence his anticipation with the latter was more than $0^{s}\cdot5$; and we risk but little in considering Bessel's difference of $0^{s}\cdot8$ from W. Struve was mainly due to himself and not to Struve. I believe astronomers in general would agree with this opinion. In 1843 and 1844 Struve was compared with all the observers who took part in the chronometric expeditions of those years, between Pulkova, Greenwich, and Altona, and from these comparisons we find that he agrees within a few hundredths of a second with the general average, including O. Struve, who was the standard observer for the expedition of 1844, and was also nearly an average observer. The comparisons with Bessel give rise to the suspicion that an average of eye and ear observations, giving each observer equal weight, might perhaps be seriously in error.

If we take the equations Bessel-Struve $= -0^{s}\cdot8$, Bessel-Argelander $= -1^{s}\cdot2$, we find enough residual error in the mean result of the observers on almost any theory to leave the conclusion as to the true average observer somewhat doubtful.

[1] The clock's daily rate as used was $5^{s}\cdot92$.

The subject has since 1885 been thoroughly followed up at Greenwich by the combination of the eye and ear and chronographic methods,* and the various older examples of large personal equation which are upon record ; for instance

Maskelyne-Kinnebrook	1795	$= -0^{s}\cdot8$
Main-Rogerson	1853	$= -0\cdot7$
Main-Lucas	1871, 1872	$= -0\cdot76$

are worth mentioning in connection with the material accumulated since 1885, chiefly to show that absolute personal errors of considerable magnitude, $0^{s}\cdot5$ or more, are to be found in either direction, and not solely as anticipations.

Observers of Argelander's type who set down transits by eye and ear $0^{s}\cdot4$ too late are not often found ; and yet that an error of more than $0^{s}\cdot3$ must exist in the case of some observers is plain ; so that the fact that either Bessel or Argelander observed transits more than $0^{s}\cdot6$ too early or too late does not seem as difficult to comprehend as it did many years ago. Mr. Main, for example, was a transit observer of Argelander's type, as was the luckless Kinnebrook in 1795 ; and Maskelyne anticipated three assistants—Dymond, Bayley, and Hitchens—by $0^{s}\cdot27$, $0^{s}\cdot18$, and $0^{s}\cdot14$ respectively ; and if the average $0^{s}\cdot20$ of these three quantities is taken as an indication, he was much like most modern observers in his manner of noting transits.

In order to put the data of the later Greenwich introductions into a shape for farther discussion, I have brought together the quantities $e'-e$ for the twenty observers who have taken part in the eye and ear transits since 1885, when the practice of observing time-stars by this method was resumed after its disuse about 1859. Of the twenty observers eight are assistants and twelve computers.

By e' I denote the amount by which each observer anticipated by eye and ear the standard chronographic transits of the Royal Observatory ; by e I denote the similar amount by which he anticipated the standard transits by chronographic registration on his own part. Hence $e'-e$ (for the standard observer $e=0$) is the amount by which each observer when he uses the eye and ear method anticipates the standard chronographic transits ; and on reading over the Introductions to the Greenwich Observations we find that for the standard observers e', and for the others $e'-e$, is persistently positive for the whole period from 1885 to 1893 inclusive. For A. D., who served as standard observer till 1890 inclusive, and for eye and ear in 1891, we find the mean of seven values of $e'=+0\cdot123$, and for L., standard observer in the two years 1892 and 1893, we find $e'=+0^{s}\cdot19$ and $+0^{s}\cdot20$ respectively. But as L. was one of the principal observers for the whole nine

* The earlier discussions at Greenwich refer to the eye and ear method, or the chronographic method used separately but not together.

years, we can readily set down the amounts $e'-e$ by which he anticipated his own chronographic transits for all these years.

For example, in 1885 e' for L. is $+0^s{\cdot}08$ and $e+0^s{\cdot}02$; hence in that year L. anticipated by eye and ear his own chronographic transits by $0^s{\cdot}06$. The sum of the nine values of $e'-e$ is $1^s{\cdot}27$ and the mean $0^s{\cdot}141$, hence L.'s mean anticipation of his own chronographic transits is slightly more than that of A. D., the former standard observer.

It would be unsafe to base any generalisation upon the work of two observers only, however skilful and experienced. For the period 1885–1893 there were in service three other astronomers who took a large share in the transit circle observations for nearly all the years, and we find the mean value of $e'-e$ for them to be as follows :—For H. T. $+0^s{\cdot}030$, seven years, or including a single observation of 1893 with half the weight of a year,

For T,	$+0^s{\cdot}052$	$7\frac{1}{2}$ years.
	$+0^s{\cdot}033$	6 years.

The case of one observer, H., has been stated, so far as his chronographic transits are concerned, in *The Observatory* for May 1896.

The mean $e'-e$ for him for the nine years is $+0^s{\cdot}511$.

Three other assistants took part in the eye and ear observations in 1892 and 1893. The values of $e'-e$ for them are respectively,

A. C.	1892	$e'-e=$	$+\overset{s}{0}{\cdot}20$
A. C.	1893	$e'-e=$	$+0{\cdot}10$
B.	1892	$e'-e=$	$+0{\cdot}07$
B.	1893	$e'-e=$	$-0{\cdot}01$
T. H.	1893	$e'-e=$	$+0{\cdot}22$

For the twelve computers tested from time to time between 1889 and 1893 we find a single one (and he is the junior computer tested in 1893 only) for whom the mean value of $e'-e$ is negative, and this for him represents one determination of e' only. For him $e'-e=0{\cdot}03$, considerably less than its probable error. Considering all the separate years' results, $e'-e$ for computers as units, we find of the nineteen such results the sum to be $1^s{\cdot}66$, and their average $0^s{\cdot}087$. This average would be modified by assignment of varying weights, but cannot be rendered negative.

The outcome of the investigation into the comparative personal equation by the two methods indicates that in the great majority of cases skilled eye and ear observers anticipate their own chronographic transits by amounts in general not far from $0^s{\cdot}1$. But the observers previously mentioned (like Argelander), who fell behind the true time of transit as much as about $0^s{\cdot}4$,

require attention at this point. These observers, so far as Greenwich is concerned, seem to be the following :—Kinnebrook 1795, Henry and Main (who nearly agreed with each other) in 1839 and some following years, and W. Ellis in the two or three years which just preceded the introduction in 1854 of the chronograph.

At any rate, the large majority of the Greenwich observers for a century have been men of the "anticipatory" type, if I may so call those who set down eye and ear transits too early as compared with their own chronographic registration or with average observers.

This represents, according to the best evidence I can gather, the following two principles :—

First, that the eye and ear method gives transits of time-stars which by different observers may be set down either too early or too late, but on the average of a number of skilled observers will be nearly correct, and the chronographic method, on the other hand, results in "observed" times of transit which are, on the average, too late by about $0^s{\cdot}1$ or more.

The eye and ear method and its results were discussed by Bessel in his classical memoirs reprinted in Engelmann's collection of the *Abhandlungen*, vol. iii. Argelander, as appears from the *Bonn Observations*, vol. vi. p. 11, accepted Bessel's theory, that Bessel "proceeded from hearing to seeing," while Argelander, to use his own words, "first saw and then heard." The questioned was tested in 1861 by the psychologist Wundt by simple experiments with a heavy pendulum, and he found that observers were, in fact, of the two types ; some of them mentally fixed the place of the moving object too far ahead in its course, and others not far enough.

With the star's images the same is doubtless the case, and the observer's habit of fixing the place mentally at the clock-beat is thus rendered measurable as a psychological phenomenon. Wundt and others have tested also the "simple reaction to a sense impression," and have found out how long it takes an observer to register an impression on any of his senses by using in the registry chronographs or chronoscopes imitated from the astronomical apparatus. It is found that in general the time occupied is from one-tenth to two-tenths of a second, and it is also found that there are two methods of registering, the "muscular" and the "sensorial," and that the "sensorial," in which the observer waits till he is sure of the sense impression, generally occupies $0^s{\cdot}1$ or more longer than the other in which the observer's attention is concentrated upon performing the act of registration. This, too, is confirmed by the astronomical experience of L. and H. (*The Observatory* for May 1896), as well as of Dr. Battermann, who employs the slower method in very precise observations of transits of faint stars.

The conclusions of this paper so far may be thus stated. The experience of observers since 1795 shows that most eye and ear

observers anticipate the true time of transits, at least if the average observer is taken as the standard.

The Greenwich experiments since 1885 indicate that the great majority when they use the eye and ear method almost without exception anticipate the time of their own chronographic transits; that the average chronographic observer registers transits after the time of their occurrence by an amount not greatly different from that which is required to register an impression on the senses; that the difference between the sensorial and muscular methods of "reaction" is confirmed by the experience of L. and H., for ten years at Greenwich.

A question which Bessel left not wholly answered, viz.: "Whether his observations of polar and equatorial stars were homogeneous," has lately assumed some importance; but I must defer till another occasion the computations which I have made, and which show that the Greenwich right ascensicns of polar stars since 1889, observed by a new method, are in close accordance with the Berlin *Jahrbuch*, which has been taken as a standard in this respect by a good many observers and has much weight.

The differences between the right ascensions of standard polar stars as derived from the absolute observations, successive double culminations observed by various astronomers, have often attracted enough attention to be mentioned, but have been usually treated as a matter of no great importance. Thus, for instance, Preuss obtained a greater right ascension of *Polaris* than W. Struve did, but the difference $0^s \cdot 84$ was possibly due to other causes.

In the arrangements for the Pulkova fundamental catalogue of 1845 this point was carefully attended to by Struve and his assistants; *Polaris* and other polar stars were observed by the individual astronomers with the following results in right ascension for 1845·0.

For *Polaris*:

			h	m	s
Schweizer	511	observations	1	3	35·74
Fuss	29	,,			34·71
Lindhagen	65	,,			35·22
Wagner	91	,,			35·36

For *H Cephei* 51:

			h	m	s
Schweizer	11	,,	6	25	59·66
Lindhagen	7	,,			59·22
Wagner	28	,,			59·28

For δ *Ursæ Minoris*:

			h	m	s
Schweizer	170	,,	18	22	19·75
Fuss	23	,,			19·45
Lindhagen	17	,,			19·72
Wagner	55	,,			19·56

It will be seen that Schweizer, who observed time-stars very nearly as W. Struve did, and was in that respect very nearly an average observer, assigned larger right ascensions to all three stars than Wagner, while his difference in the same direction from Fuss, who, however, did not observe *H Cephei* 51, was also considerable. We have for *Polaris*, Schweizer-Fuss = 1^s·03, or for δ *Ursæ Minoris*, Schweizer-Fuss = 0^s·30 or 0″·27, reduced to the equator.

(From a paper by Mr. Sokoloff on the movement of the pole as determined by transit observations, in *Mélanges Mathématiques et Astronomiques*, vol. viii. p. 799.)

Similar differences to those between the Pulkova observers about 1845 are indicated among those of 1880 to 1887.

The following are the corrections of the assumed right ascensions of the three polars, *Polaris*, *H Cephei* 51, and δ *Ursæ Minoris*, as observed since 1880 by three observers employing both the eye and ear method and chronographic registration.

(1) Observations by eye and ear :

	Polaris.	H Cephei 51.	δ Ursæ Minoris.
	s	s	s
Wagner	−0·12	−0·33	−0·22
Wittram	−0·24	−0·33	−0·21
Harzer	−0·76	−0·61	−0·51

(2) Registered observations :

Wagner	+0·45	+0·10	+0·11
Wittram	−0·39	−0·28	−0·13
Harzer	−0·68	−0·58	−0·41

The vol. i. lately published of the *Annals of the Strassburg Observatory* affords indications of similar differences in the observations of *Polaris* chronographically registered.

The observers were Professor Schur, acting director, and Messrs. Wislicenus, Stechert, Kaufmann, and Dr. Leitzmann. The observations, like those for the Pulkova fundamental catalogues, were referred to the meridian by the help of marks with long focus lenses, the construction attributed to Rittenhouse, introduced at Pulkova by W. Struve. Hence the corrections to the tabular right ascension are based upon double culminations. These corrections denoted by χ are given by Professor Becker as follows :—

	s			s
χ for Schur	−0·58	mean error		±0·21
,, Wislicenus	−0·54	,,	,,	±0·13
,, ,, ...	−0·68	,,	,,	±0·12
,, Kaufmann	+0·36	,,	,,	±0·10
,, ,, ...	−0·02	,,	,,	±0·46
,, Stechert	+0·98	,,	,,	±0·30
,, Leitzmann	+0·65	,,	,,	±0.36

The two groups of Dr. Wislicenus's observations are separated in the *Annals* because of an interchange of object-glass and eye-piece which might produce a slight difference through alteration of the field illumination. But the difference of the two quantities $-0^{s}{\cdot}54$ and $-0^{s}{\cdot}68$ is $0^{s}{\cdot}14$; less than its mean error $\sqrt{(0^{s}{\cdot}13)^2+(0^{s}{\cdot}12)^2}$ or $\pm 0^{s}{\cdot}18$, so that we can combine the two groups into one result, $-0^{s}{\cdot}62$, and we thus see that Dr. Wislicenus observes *Polaris* nearly uniformly with Professor Schur, and decidedly earlier than either Kaufmann, Stechert, or Leitzmann. His difference from Dr. Stechert is $1^{s}{\cdot}60$, about five times its mean error, and from Dr. Leitzmann $1^{s}{\cdot}27$, with a mean error of not quite a third of the amount.

It will now be seen that a "polar equation," as I may call it, is indicated for the Pulkova observers of 1845 and for their successors since 1880, and also for the Strassburg astronomers of 1883–1888.

But without some process which shall pretty thoroughly eliminate these differences no definite standard can easily be fixed; or, in other words, no standard catalogue of polar right ascensions is practicable, and the need of such a catalogue is apparent. The Greenwich method of observing transits of *Polaris* and the other azimuth stars is not known to be liable to any special personal equation, except the trifling difference between the registration by the two hands.

Of course the clock corrections are obtained by the ordinary methods, and as these produce an average error for time-stars amounting only to about a tenth of a second, we can see that its influence on the right ascension of *Polaris* and other close stars will be trifling. Moreover, the "muscular" method of registration, Professor Newcomb's Method A, is preferable for ordinary time-stars.

It is possible that the delay of the sensorial method, Method B, according to Newcomb, is different for polar and for equatorial stars, and it is not only desirable to investigate the "polar equation" for the standard azimuth stars, but for others of less declination, by both methods, Bradley's and the chronographic.

In Professors Helmert and Albrecht's work on the longitudes of the Prussian Geodetic Institute we find that the Repsold Transit Micrometer, which acts in an analogous manner to the "Greenwich Method," but in a wider range of declination, does good service, and reduces both ordinary personal equations and those referring to polar stars to a far less amount than previous experience indicates.

In attempting to fit a series of transit observations to a standard catalogue, the Pulkova astronomers have adopted a method which indicates the polar equations pretty clearly, and also shows how to eliminate it to a large extent. This process is most clearly set forth in Dr. Romberg's excellent catalogue of 5634 stars for 1875.

Romberg found in using the standard catalogue prepared by Vice-Director Wagner that his own tendency was to observe by eye and ear slow moving stars later by $0^s\cdot025$ than Wagner, when for Wagner the mean results of his two methods, eye and ear and chronographic was taken. Romberg's observations at Pulkova began in 1877. Some years earlier, about 1870–1877, he had observed the fundamental stars of Wagner's list at Berlin, and his observations have been reduced by Dr. Marcuse.

The conclusion as to polar equation which I derive from Dr. Marcuse's work is that, at Berlin also, Romberg observed the polar stars later than the standard, the amount being about $0^s\cdot019$, not quite so much as at Pulkova.

To eliminate this polar equation from the Pulkova secondary catalogues requires systematic corrections, and the process becomes a little intricate.

It is conceivable that in practice astronomers will be compelled to resort to the Repsold Micrometer for transits of stars more than 5° from the pole, or to photography.

At any rate, the extension of the "Greenwich Method" to greater polar distances is desirable if practicable. Meanwhile nothing is lost by following for the present the best modern practice in ordinary observations of transits.

There are six stars within 5° of the north pole whose right ascensions are regularly observed at Greenwich by the new method, and their co-ordinates are given in the Berlin *Jahrbuch* from Auwers's compilation and based upon the standard of Wagner's observations about 1865.

These six stars are:—1. *Cephei* 43=2 *Ursæ Minoris*; 2. *Polaris*; 3. Groombridge 750; 4. *Cephei* 51; 5. δ *Ursæ Minoris*; 6. λ *Ursæ Minoris*. Besides these there are six others which are also regularly observed in the same way, viz.:—

1. Groombridge 1119.
2. Bradley 1672.
3. Groombridge 2283.
4. Groombridge 3548.
5. Cephei 32=Bradley 2993.
6. Cephei 39=Bradley 3147.

Of the second list of six, No. 1, No. 3, and No. 4 are not in Bradley's catalogue, but all have been abundantly observed since 1814 by W. Struve and other astronomers, so that their proper motions can be accurately determined without applying doubtful systematic corrections to Piazzi or Groombridge, and the best standard polar catalogue for immediate use which I can suggest would be obtained from the Greenwich right ascensions 1889–1893, brought forward with proper motions obtained from the mass of existing reduced observations taken before 1889.

In the use of such a catalogue the observers should compare themselves with its standard by the process indicated in Romberg's

catalogue of 5634 stars; that is, by determining polar deviations (Bessel's n) from close stars above and below pole and nearly at the same hours; for instance, *H Cephei* 51 and δ *Ursæ Minoris*.

My own attempts to determine my "polar equation" by similar comparisons with the *Jahrbuch* standard are given in the *Williams College Catalogue of North Polar Stars*. I found that in the years 1882–1888 I observed by eye and ear slow moving stars relatively about $0^s{\cdot}006$ later than the standard. By chronograph I observed about $0^s{\cdot}010$ or $0^s{\cdot}012$ later than the same standard. These quantities were so small that it was difficult to be certain of them, partly because of the small number of *Jahrbuch* stars available.

The difficulty of discriminating between Professor Smyth's 'instrumental swerving' and personal slowness with the polar stars could have been mitigated by the employment of a more extensive list of close polars, but this was impracticable, for the very stars were among those of such a list I wished to determine, and they were not to be mixed with the determining stars, and so the new Greenwich stars, Groombridge 1119, and the others were set down as observed only when their right ascensions were based upon instrumental corrections determined from Pulkova (*Jahrbuch*) stars. In other words, I did not employ Pond's method of fixing these particular zero points, but contented myself with adding $0^s{\cdot}006$ to a value of n derived from an upper culmination, and subtracting that amount from an n derived from a lower culmination, or, in the cases when that was practicable, taking the mean of the two values of n, when of course the $+0^s{\cdot}006$ and the $-0^s{\cdot}006$ would cancel each other.

The Pulkova astronomers in 1893 examined their "polar equations" by eye and ear comparison again with the same standard of Wagner, and one of them, Mr. Ditshénko, has published a paper (*Melanges Mathématiques et Astronomiques*, vol. vii., pp. 543–553) entitled "L'équation personnelle dans les observations des passages des étoiles polaires." He finds that, nearly as in 1877–1884, Romberg observed polar stars later than the standard by the amount $0^s{\cdot}026$. But three other observers, Morine, Seraphimoff, and Ditshénko himself, observed them earlier, namely, $0^s{\cdot}042$, $0^s{\cdot}015$, and $0^s{\cdot}025$ respectively, and the corresponding corrections are applied to the respective values of n, thus rendering them all homogeneous, but leaving right ascensions reduced by their aid still subject to the observed polar equation.

The observations of secondary right ascensions can be made more homogeneous by additional observations of secondary polars in various declinations by both the eye and ear, and the chronographic method, using as primary polar right ascensions those of Greenwich 1889–1893, and by comparing the results for azimuth or polar deviation from stars above and below pole, so as to apply the Pulkova correction to n, and then put on record the observer's peculiarity in that respect. The stars not in the

Greenwich list of twelve will in that case be affected with the observer's polar equation as the application of the Pulkova correction will eliminate the influence of their equation upon the polar deviations, but not on the final right ascension of the secondary stars so determined; for example, Romberg's Pulkova values of n were thus reduced to agreement with Wagner's standard, but not his determined right ascensions. These exhibit a tendency similar to that of his polar deviation; that is, he observed stars beyond the zenith of Pulkova or Berlin, respectively, later than the standard.

The light equation or *Helligkeits Gleichung* has been investigated by various astronomers and with very varying results.

It is found that by the chronograph observers register the transits of faint stars later than they do those of the brighter stars used for clock correction. The reason of this seems to be a psychological one; a faint impression on the senses is reacted to, according to Wundt and others, later than a stronger one, while by eye and ear a star plainly visible is observed at its transit more nearly in a uniform manner with the brighter ones. Argelander's experience is this: by eye and ear he noted the transits of very faint stars $0^s{\cdot}48$ *earlier* than he did those of stars distinctly visible in his illuminated field. This he suspected, and Professor Auwers has confirmed his suspicion, and even over-confirmed it, for Argelander suspected his variations would be $0^s{\cdot}2$ or $0^s{\cdot}3$, and he correctly, it seems, attributed it to a reversal of his usual mental process of "seeing first and then hearing." The stars to which the usual habit applied were those of 8·7 mag. or brighter; those for which the reversal took place fainter ones, down to 9·7 mag., and observed by taking very special precautions, such as keeping the room dark and writing the times on a sheet of paper under a heavy black framework so that the eye was kept as nearly at rest as possible.

Another form of personal equation (discovered by Dr. Gill) is that caused by opposite direction of motion to that which is familiar. It is very sensible in eye and ear work, and seems there to be due to the observer's somewhat imperfect fractioning of the seconds. This was apparently first noted by Professor Benjamin Peirce and is mentioned in *Chauvenet's Spherical and Practical Astronomy.* This form of equation has been pretty thoroughly tested by the Greenwich observers since 1885 and found trifling for polar stars and still less important for time-stars chronographically registered. The experiments for time-stars are summarised in Professor Turner's paper in the *Monthly Notices*, vol. xlviii. p. 14.

This form of personal equation in chronographic observations of time-stars seems to be indicated by the differences which Professor Küstner and Mr. R. H. Tucker find between stars observed north and those observed south of the zenith. The former are delayed in registration by $0^s{\cdot}02$ or $0^s{\cdot}03$ as compared with the latter.

The personal equations depending on magnitude can be best and most easily studied by observing relative right ascensions of stars in loose clusters which have been micrometrically measured either heliometrically or from their photographs. Examples of such clusters are the *Pleiades*, *Praesepe* and the cluster in *Coma Berenices* lately measured by Dr. Chase with the Yale heliometer. *Praesepe* has been especially well studied by Professor Schur, now Gauss's successor at Göttingen.

It will be seen from what precedes that in the first place the general theory of Bessel as to personal equation is confirmed, and that the same is true with regard to Wundt's explanation of the eye and ear process. Moreover, the eye and ear method is shown to give results capable of employment as nearly accurate on the average. And Wundt's comparison of chronographic registration with the psychological experiments on "simple reaction" is also shown to be justified by the fact that the time required for chronographic registration by the "muscular" method is about the same as that taken up by the shortened or rapid reactions obtained by the same method.

Astronomers need to pursue the subject into more detail, especially in the line of transit observations of stars in loose clusters, comparing them with micrometrical measurements. And there should also be more inquiry into the laws of that portion of the subject which I have called "polar equation," an inquiry which is greatly facilitated by the introduction at Greenwich of the new manner of galvanic registration of the transits of standard stars employed to determine instrumental azimuths.

In his *Grundzüge der physiologischen Psychologie* (3rd. edition: Leipzig, 1887), Professor Wundt ascribes the early experiments, which he describes as "Complicationsversuche," to the impulse of Bessel's discovery of personal equation, and his later "Reactionsversuche" to the experiments made to eliminate personal equations in longitude operations. Thus we see that the riddles which Bessel brought forward, but did not completely solve, have given rise to, and have been greatly helped towards, a more complete solution by the rise of a new branch of science—experimental psychology—which is now pursued in many of the most prominent universities of the world as a new department of study, and it is now possible to combine in a certain degree the study of the human mind with that of the physical universe, and thus to contribute towards the restoration of the unity of philosophical study.

The Spectrum of β Lyræ, as observed at Stonyhurst College Observatory in 1895. By the Rev. Walter Sidgreaves, S.J.

The collection of photographic spectra of *β Lyræ*, obtained with the light-power of the Perry memorial objective, consists of over 100 plates. The series was commenced in the early part of May and finished in October. During these months all other night work was considered of secondary importance. Particular attention was given to the night preceding the chief minimum, and we have thirteen plates belonging to the last day of the period, or within twenty-two hours of the minimum. Three of these cover the minimum passage and belong both to the last and to the first day of the period.

It was at first intended to make use of only three plates for each of the thirteen days, as mentioned in our report of the Observatory in the *Monthly Notices* of 1896 February. But as the micrometer work upon the plates progressed, it became evident that nearly all the plates should be used; for it was found that some details were seen on plates noted as inferior, better than on other more perfect-looking photographs. The total number of plates carefully examined is eighty-six. Some of these will be found to occupy two places in the appended catalogues of wave-lengths. In these cases half of the trailed spectrum belongs to one, and half to the following day of the light period, the whole trail being long enough to represent two separate exposures.

The slitless spectrograph employed for the series has been already fully described, partly in the *Memoirs*, vol. li, and partly in the *Monthly Notices*, vol. lvi. It is the spectrograph which was used for the *Nova* of 1892, with the alteration mentioned in the report of 1896 February. Great attention was given to this alteration, and we are largely indebted to Mr. Hilger for the expeditious way in which he helped the successive steps by which we finally arrived at the true configuration and relative densities of the component glasses for bringing the rays between D and H parallel on to the prism.

The greater stability of the instrument, owing to this alteration, has proved to be a great gain. The concave collimator having to take the cone of light before it arrives at the focal plane of the object glass, we have, in place of a long appendage to the eye end of the telescope tube, a short compact spectrograph fitted into a massive metal holder firmly screwed up in the position of an ordinary eye-piece. Its behaviour in different positions of the telescope is shown by the following scale readings for the prominent lines in the bright stars :—